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HVAC Characteristics And Occupant Health

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Recently, increasing health complaints among workers in indoor, non-industrial environments have prompted research to identify factors associated with these complaints. This article summarizes a study,[1,2] based on surveys including 2,435 workers in 80 office buildings, of the associations between HVAC design and maintenance characteristics or building maintenance characteristics and work-related lower respiratory symptoms, allergic symptoms, and asthma development.

Methods

Study data were collected in the Health Hazard Evaluations (HHE) program of the U.S. National Institute for Occupational Safety and Health (NIOSH). Following publicity from an October 1992 national television news broadcast, NIOSH received many requests for HHEs in indoor work environments. Limited resources of the HHE program allowed evaluations of 160 buildings, selected from 500 requests received by February 1993. The primary evaluation area typically was a floor or section of the building of concern to the evaluation requesters.

The environmental evaluation consisted of an observational walk-through survey, with completion of information checklists regarding the entire building, the evaluation area, and the components of the HVAC systems. In addition, health questionnaires were completed by all occupants present in the evaluation area on the day of the survey. All symptom data were self-reported. Evaluations were conducted between April and July 1993. This analysis includes data from 80 of the 105 office buildings evaluated, with complete, correctly collected data.

Among the 2,435 respondents providing health questionnaire data, 814 (34%) were male, 1,607 (66%) were female, and 1,304 (54%) were non-smokers. Respondents ranged in age from less than 20 years to more than 60 years. Overall, they had worked a median of four years in the office building, although this time varied between less than a year to 35 years.

A "work-related symptom" was defined as one reported at least once per week in the previous four weeks that improved when the employee was away from the work site. Two symptom groups were defined. The "multiple lower respiratory symptom" group required having at least three of the following work-related symptoms: shortness of breath, cough, chest tightness, and wheezing. The "multiple allergic symptom" group required all three of the following: sneezing, eye irritation, and stuffy/runny nose/nasal congestion. Diagnosis of asthma by a physician after the respondent began work in the building was determined.

Certain HVAC and building characteristics, e.g., poor drainage from coil drain pans, as noted by NIOSH staff during walk-through surveys, were considered potential risk factors or protective factors for health outcomes. These characteristics were included as variables in statistical analysis models. This summary discusses variables related to HVAC system design and maintenance, and building maintenance.

The statistical models determined the strength and statistical uncertainty of associations between health outcomes and the building and HVAC characteristics. The models calculate values of relative risk (RR). The RR represents the magnitude of the increase (or decrease) in the prevalence of a health outcome among occupants of buildings with particular HVAC or building characteristics, relative to the prevalence of the health outcome in buildings without that HVAC or

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building characteristic. The models produced values of RR adjusted for the effects of age and gender. As examples, an RR of 1.5 indicates that the prevalence of the health outcome is *increased* by 50% in buildings with the risk factor, while an RR of 0.7 indicates that the prevalence of the health outcome is *decreased* by 30% in buildings with the risk (or protection) factor. To convey results using familiar terminology, results are presented as percent increases or percent decreases in prevalence of health outcomes.

Suspected risk (or protection) factors will sometimes be associated by chance with increased or decreased health outcomes in the sample included in the study (in this case, 80 office buildings), despite the absence of an association in the larger population (in this case, all office buildings). Consequently, the statistical models that calculated values of RR also calculated the probabilities that the observed associations were merely chance associations. The results presented in *Table 1* include only increases or decreases in health outcomes that have a 10% or smaller probability of being the result of chance (denoted by $p \leq 0.10$). For most of these results a 5% or smaller probability exists that the increase or decrease in the health outcome is due to chance ($p \leq 0.05$).

Results

Lower Respiratory Symptoms

Fifteen HVAC variables hypothesized to be risk factors were associated ($p \leq 0.10$) with 60% to 210% increases in prevalence of lower respiratory symptoms. Most of these HVAC conditions were indicators of debris, moisture, or other pollutant sources within 25 ft (7.6 m) of the outside air intake of the HVAC system or within the HVAC system. The two HVAC conditions most associated with increased lower respiratory symptoms were debris in the outside air intake and poor or no drainage from the cooling coil drain pan. Three building maintenance variables were associated ($p \leq 0.10$) with a *reduced* prevalence of lower respiratory symptoms: daily vacuuming; application of interior pesticides; and monthly floor stripping and waxing.

Allergic Symptoms

A cooling tower was associated ($p \leq 0.10$) with a 70% reduction in allergic symptoms. Three HVAC maintenance variables (no test and balance report, poor HVAC cleanliness, ductwork never cleaned) and two building maintenance variables (daily surface dusting, application of interior pesticides) were associated ($p \leq 0.10$) with 30% to 80% increases in allergic symptoms.

Asthma

Two HVAC maintenance variables (dirty filters, debris in outside air intake) and one building maintenance variable (recent renovation including new drywall) were associated ($p \leq 0.10$) with 100% to 150% increases in asthma diagnosed after beginning work in the building. Three variables (ductwork never cleaned, daily surface cleaning with solution, daily surface dusting) were associated with a decrease in asthma diagnosed after beginning work in the building.

Limitations

When considering the results of this study, it is important to remember that an association does not prove causation and that some of the reported associations are still likely to be chance associations, e.g., if one performs 100 statistical tests, ten chance associations with $p \leq 0.1$ would be expected. In fact, some of the findings are contrary to expectations. For example, it seems unlikely that a renovation including new drywall within the last three weeks could cause an increase in asthma diagnosis, since medical examinations and diagnoses for asthma would usually take more than three weeks. Some findings are apparently contradictory, e.g., air ductwork never cleaned is associated with an 80% increase in allergy symptoms and a 40% decrease in asthma diagnosis, an apparently contradictory set of findings since allergy underlies most cases of asthma.

Another limitation is that the analyses did not account for correlation among risk factors. Many of the risk factors in this analysis existed in combination with multiple other risk factors, as is commonly found in investigations of complaint buildings. For example, in the 19 buildings with no scheduled air handler inspections, lack of cleanliness in the HVAC system was noted in 17 buildings, problems with the particulate filtration system were noted in 14 buildings, testing and balancing reports were not available in seven buildings, and the air ductwork had never been cleaned in six buildings.

Other limitations are mentioned in the study's papers.[1,2]

Interpretation of Results

Despite these limitations, this study identified many suspected risk (or protection) factors. It is unlikely that such a large number of relatively strong associations are the result of chance. The findings of this study suggest that adverse health outcomes among building occupants may be reduced through improvements in HVAC system design and maintenance and by maintaining outside air intakes distant from potential pollutant sources. Consequently, the overall results of this study provide support for the implementation of available guidelines for maintenance and design of HVAC systems.[3] The implications for building maintenance are less clear because several of the building maintenance variables are associated with both decreases and increases in health outcomes. The most consistent findings were for daily surface cleaning with solution and for daily vacuuming, which were suggested as being health protective.

References

1. Crandall, M.S., W.K. Sieber. 1996. "The NIOSH indoor environmental evaluation experience. part one: building environmental evaluations." *Appl. Occup. Environ. Hyg.* 11(6):533–539.

2. Malkin, R., T. Wilcox, W.K. Sieber. 1996. "The NIOSH indoor environmental evaluation experience. part two: symptoms prevalence." *Appl. Occup. Environ. Hyg.* 11(6):540–545.

3. U.S. Environmental Protection Agency. 1991. *National Institute for Occupational Safety and Health: Building Air Quality. A Guide for Building Owners and Facility Managers.*

Table 1 (right): Increases and decreases in health outcomes associated with variables of HVAC design and maintenance and building maintenance. The table lists only increases or decreases that have a 10% or smaller probability of being chance findings. When there is a 5% or smaller probability that the increase or decrease in the health outcome is a chance finding, the increase or decrease is shown in bold type.

Category	Variable	Increase in Multiple Lower Respiratory Symptoms	Increase In Multiple Allergic Symptoms	Increase in Asthma Diagnosed After Beginning Work In Buildings
HVAC Design	**Outdoor Air Intake Within 25 ft of:**			
	Standing Water	**130%**	—	—
	Exhaust Vents	**140%**	—	—
	Sanitary Vents	**120%**	—	—
	Cooling Tower	—	**–70%**	—
	Vehicle Traffic	**80%**	—	—
	Trash Dumpster	**110%**	—	—
HVAC Maintenance	**No Scheduled Air Handler Inspection**	**100%**	—	—
	No Testing And Balancing Report Available	—	**80%**	—
	Particulate Filtration System:	—	—	—
	Filters Not Secure in Place	**120%**	—	—
	Dirty Filters	**90%**	—	**100%**
	HVAC Cleanliness*	**80%**	30%	—
	HVAC Condition:			
	Debris Inside Air Intake	**210%**	—	**100%**
	Residue/Dirt in Drain Pans	**60%**	—	—
	Poor or No Drainage from Pans	**200%**	—	—
	Dirty Ductwork	**110%**	—	—
	Presence of Moisture in HVAC System	**120%**	—	—
	Air Ductwork Never Cleaned	180%	**80%**	–40%
Building Maintenance	**Daily Surface Cleaning With Solution**	—	—	**–50%**
	Daily Vacuuming	**–50%**	—	—
	Daily Surface Dusting	–40%	**30%**	**–50%**
	Interior Pesticides Have Been Applied	**–50%**	**50%**	—
	Floor Stripping and Waxing Done Monthly	–60%	—	—
	Renovation Including Installation of New Drywall Within Last Three Weeks	—	—	**150%**

* Any of 10 conditions in the HVAC system: dusty air handler, dirty sound liner, presence of debris inside air intake, moist sound liner, dirty coils, residue/dirt in drain pans, poor/no drainage from drain pans, dirty or mist ductwork, or dirty duct liner.